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Development of a Real-Time Crime Management System in Southwestern Nigeria: The Mobile Application

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Abstract. Effective crime reporting in the Southwestern Nigeria has been stymied through demoralization of security personnel, institutional corruption and dearth of state-of-the-art equipment. Even in the face of digitization of the economy and increasing use of micro-blogging platforms and messaging apps, the security situation in the region has only worsened. In order to mitigate the growing crime rate, several platforms in the form of mobile applications and websites, have been proposed while some have already been introduced to the general public. However, the major weakness of the existing solutions is that the underlying crime management systems are not adoptable by every possible security outfit available. Hence, the existing systems are not scalable and auditable. To this end, this study aimed to design and develop a system for effective real-time crime reporting and management for southwestern Nigeria. The system consists of user-centered mobile application and administrative web application. This paper presents the development of the mobile application part. The Unified Modeling Language (UML) was adopted for designing the mobile application by following the steps in Waterfall software development technique. The client side of the mobile application was developed using Google Flutter Software Development Kit (SDK) in Android Studio Integrated Development Environment (IDE), while the server side of the application was built using Node.js JavaScript framework and SQL Database. The developed software system was evaluated using alpha and beta testing by module testing and getting feedback from real users based on certain predefined criteria, including *User Interface*, *Functionality*, *Clarity* and *Maintainability*. With a percentage functionality of 91% and maintainability of 94%, the developed mobile application performed satisfactorily and effectively serves its purpose.

Keyword: Crime incident, Crime reporting, Crime management, Mobile application, GTISMA, Law enforcement agency

Introduction

The proliferation of mobile phone subscribers in Nigeria has made the process of sharing information easier. For instance, messaging apps, such as WhatsApp and micro-blogging platforms, such as Facebook and Instagram, which are now common amongst the young populace, have made the process of sharing videos, texts and voice notes seamless. Hence, one would expect that the spate of criminality would reduce since there would be more than sufficient information that could be utilized by security operatives in Nigeria for effective service delivery. Paradoxically, this is not the current reality because in recent

times, misdeeds, such as banditry, armed robbery, rape and other social vices have increased meteorically beyond our expectations. National security outfits, including the Nigeria Police Force (NPF) and National Security and Civil Defence Corps (NSCDC) have intensified efforts to reduce criminality. However, they are constantly bedeviled by a shortage of state-of-the-art equipment, motivation, existence of internal compromisers and most importantly, unreliable crime reports from the general public. This has an enormous domino effect on the spate of criminalities, food security, and concomitant demoralization of security personnel. For instance, in the North West, Nigeria, banditry has resulted to the displacement of thousands of people, hindering inter-state trade, and cutting major food supplies throughout the country.

Towards the end of the year 2020, social media platforms such as Instagram, Twitter and Facebook were used by some people to report the 'ENDSARS' protests at the Lekki Toll Gate, Lagos, Nigeria in real-time. However, since these social media platforms are largely not suited to security outfits such as the NPF and NSCDC, most reports from these platforms are often times not taken seriously and in recent times have been controversial.

When crime incidents are reported from different sources, security experts would most likely have contradicting evidence and even falsified information, which could potentially go viral in minutes. Hence, security analysts and operatives would have a difficult time confirming crime incidents and visiting the crime scene in a timely manner. The Federal government of Nigeria has consistently employed progressive techniques to combat crimes. However, one ingredient that could help alleviate crime rates is adapting information and communication technology in this regard.

Egye and Ugbedeojo (2022) assessed the intelligence-led policing in the prevention and control of kidnapping crimes in Federal Capital Territory of Nigeria, and determined the challenges that intelligence-led policing encounter in Nigeria. They recommended that government should commit more resources toward intelligence-led policing.

A handful of technological solutions have been proposed and rolled out to tackle the challenges of timely response to crime incidents. However, the existing solutions do not incorporate comprehensive monitoring and management of crime reports and cannot be considered as one-size-fits-all solution for the NPF, NSCDC, and other established security outfits. To this end, we proposed a software platform titled *Geospatial Technology-Based Information System Mobile Application (GTISMA)* that provides a seamless platform for reporting, monitoring and approving crime incidents. It consists of both user-centered mobile application and administrative web application. GTISMA fills up the gaps that are immanent in the existing solutions.

The mobile app component of the software solution facilitates real-time crime reporting from the scene of the incident to the office of the "crime fighters." These reports are handled in a timely manner by the designated technical/administrative officer who determines the authenticity of the reports and subsequently confirming them so that on-field officers can carry out investigation and initiate the arrest of offenders. The web component offers an interface to designated technical/administrative officers for visualizing and confirming reported crime incidents.

In this paper, the mobile application is discussed, highlighting the software development cycle, and the technologies that were utilized in the process of developing the software solution. The remainder of this paper is structured in the format: Section II (Literature Survey) explores the proposed and already-deployed technological solutions for reporting crime incidents; Section III (Material and Methods), shows how our technological solution was developed from the ideation stage to deployment. This section is followed by the Results and Discussion, where the performance evaluation of our proposed solution is

reported. This study culminates in Conclusion, which summarizes the entire work, and propose future research directions.

Literature Survey

In order to tackle the problem of effective crime reporting, several production-level software solutions have already been developed and deployed to digital distribution services, including Google PlayStore and AppStore. For instance, 'HawkEye', a crime reporting mobile app solely developed for the NPF, is currently hosted on Google PlayStore. HawkEye provides a platform for anonymously reporting crimes to the Police by video, voice or text in real-time (The Guardian, 2017). However, an objective consideration of its reviews amongst its active users showed that some users are still having difficulty in getting past the registration stage and one-time-password (OTP) confirmation. In addition, some users complained about poor interface design and user experience.

Another solution was proposed in Oludele *et al*. (2015), in which a computerized real-time crime management system (CRMS) was developed for managing crime records. This solution was intended to assist National Security Agencies in managing crimes and carrying out background checks of criminals (Oludele *et al*., 2015). The authors anticipated that national security will be improved with this solution. Notwithstanding the advantages of this system, even though other similar crime databases, such as Nigeria Data Portal exist, the security of Nigeria has worsened (Nigeria Data Portal, 2014). This implies that having a compendium of crime data will not provide a lasting solution to the prevailing security situation of Nigeria.

Omoregbe *et al*. (2019) designed and implemented an Electronic Policing (E-Policing) system for reporting crimes in Nigeria. With the goal of tracking and controlling crime rates in Nigeria, the authors' main goal was to provide cloud computing as a better alternative to manual policing. However, the E-Policing system was developed as a web application and hence, it is not deployable on handheld mobile devices, which account for almost 190 million subscribers in Nigeria (Nigerian Communications Commission, 2021). In addition, the proposed E-Policing platform did not separate crime management from crime reporting.

Unlike other existing solutions, our work provides a solid framework for reporting crime in real-time coupled with ensuring that potential users of the solution have great user experience. In addition, our proposed system considered scalability in the context of its usage by all security agencies in the country.

System Design and Implementation

In this study, we implemented our proposed system using the Waterfall software development model. The Waterfall model is a sequential software development technique that progresses steadily from project requirements to conclusion. The model aids the documentation of any software project in advance. The waterfall model (Figure 1) was chosen over others because of its flexibility and simplicity.

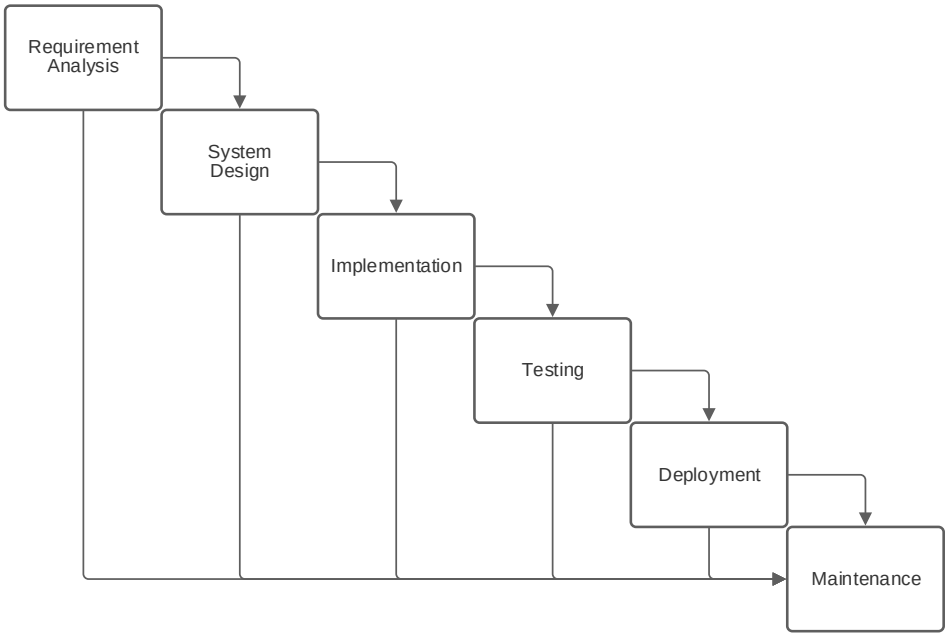


Figure 1: Waterfall model

Requirement Analysis

We begin this subsection by establishing the philosophy for developing the proposed system and give an overview of GTISMA system architecture and requirements. The GTISMA system architecture is illustrated in Figure 2. The entire GTISMA system is divided into GTISMA Web (GTISMA-W) and GTISMA Mobile (GTISMA-M). On the one hand, an eyewitness (or observer), who has already installed GTISMA-M reports on-going crime incidents by providing multimedia data (in the form of video, audio and text). These data are saved to a cloud service via application programming interfaces (API's). On the other hand, GTISMA-M is developed to target IT experts (or Admin officers) in law enforcement agencies. Admin officers who have already been authenticated in the GTISMA-M platform can access crime reports based on their location of deployment and their level of accessibility. These real-time crime data are fetched from the cloud storage and rendered on the web platform. On-field security officers can equally have access to the GTISMA-M admin platform in order to expedite crime investigations.

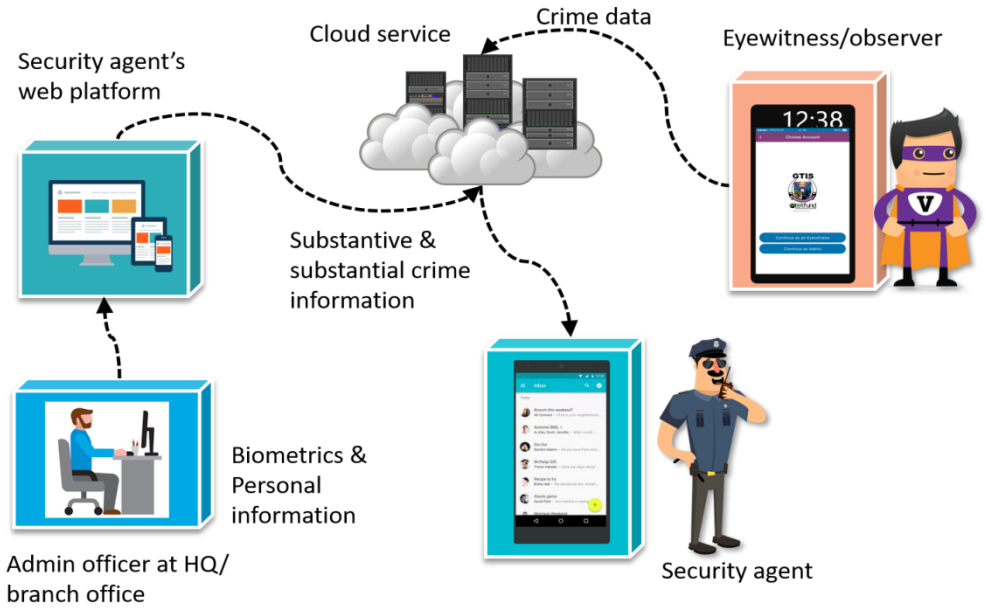


Figure 2: GTISMA system architecture

The remaining five stages (System Design, Implementation, Testing, Deployment and Maintenance were implemented differently for GTISMA mobile application and GTISMA administrative web platform.

Mobile Application System Design

Prototyping

Following extensive deliberations and ideation, we sketched the user interface (UI) of GTISMA mobile app and created wireframes, placing elements in their right positions while factoring in good user interactivity. Sequel to this activity, we used a SaaS prototyping tool, Adobe XD, to implement the wireframes and add some functionality to the elements of the UI. Adobe XD was chosen over other existing tools, such as Proto.io, Balsamiq, Justinmind, and InVision, because it offers a better simulation of a real product. Figure 3 illustrates the prototype that was produced using the Adobe XD tool.

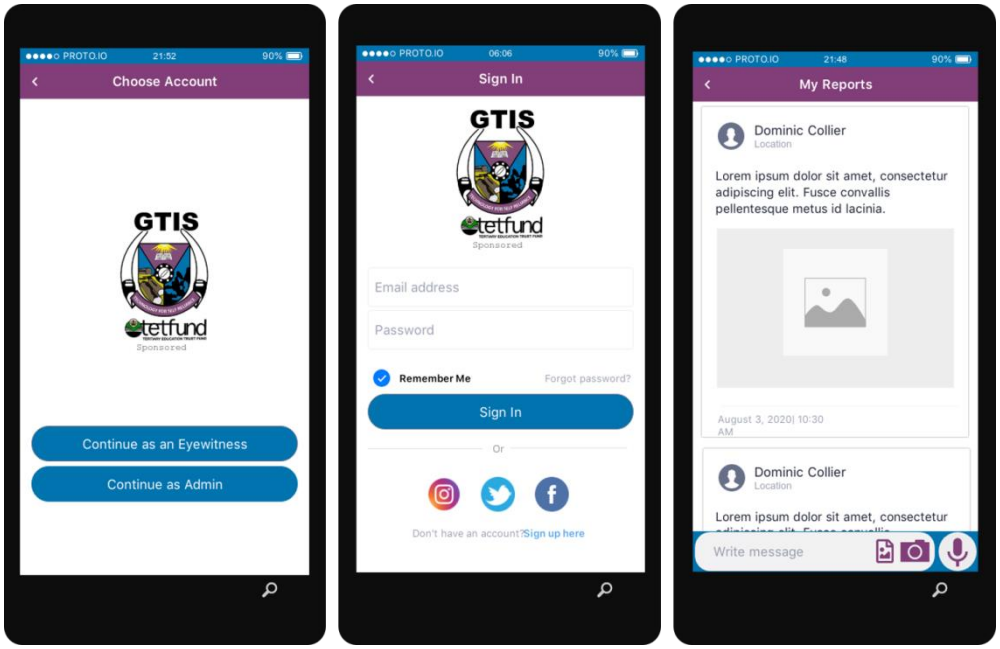


Figure 3: The Prototype

Qualitative Analysis

A distributable version of the GTISMAM prototype was obtained and shared amongst members of the research group. The prototype was installed and its interactivity and minimalistic features were tested. Suggestions that could potentially improve the performance of the minimum viable product (MVP) as well as its value were harvested. Furthermore, stakeholders' meetings involving the major players (security outfits) were organised and their responses to the MVP was analysed qualitatively and used to upgrade the features of GTISMAM MVP. Feedbacks regarding the improvement of the MVP were collated and the most salient suggestions that were relevant to the target market and end goal of the product were used to re-factor the GTISMAM prototype. This greatly improved the user interface design in addition to its interactivity.

Functional Module Design

The functional modules of both GTISMA mobile app and web platform were designed and the interconnection and flow of information between the modules are presented in this subsection. Object-oriented programming design concepts were used in depicting the interaction between these modules. In this subsection, the UML Class Diagram, UML Sequence Diagram and UML Use Case Diagram were used to illustrate the functional modules of the mobile app.

a) UML Class Diagram: The UML Class Diagram is a static diagram that is used to represent the static structure of an application. It provides a visualization, description and documentation of different aspects of a software system, ensuring that they are convertible to executable program codes. UML class diagrams facilitate the realization of a software system based on the requirements of the user (Nikiforova *et al.*, 2011). The mobile app's UML class diagram is shown in Figure 4.

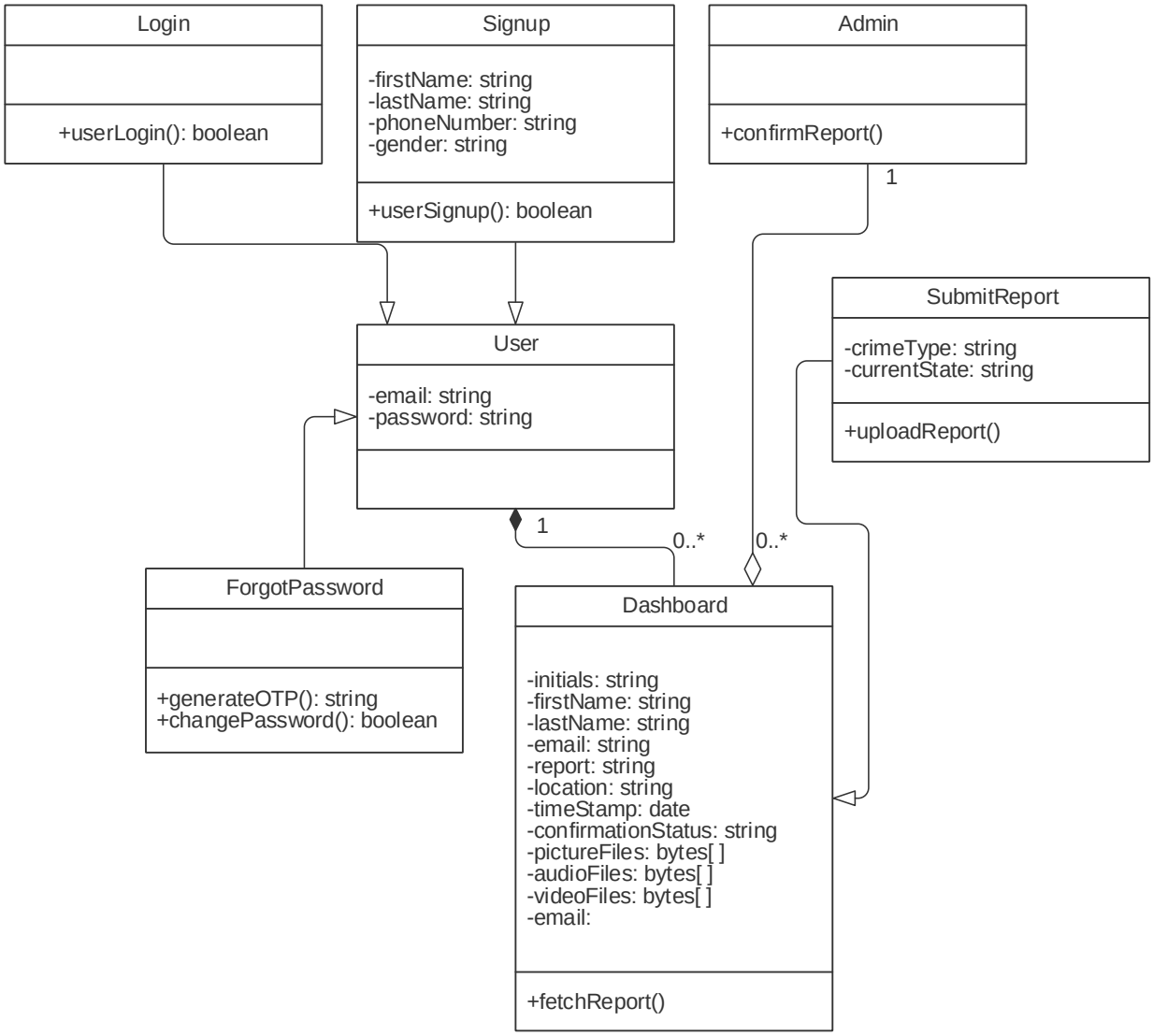


Figure 4: The Mobile App's UML Class Diagram

Login, *Signup* and *Admin* classes inherit the attributes of the *User* class. Each class has its specific method declaration that defines the task undertaken by the class. The *Dashboard* class contains attributes that enables the rendering of reports in a list format. *Admin* class has a relationship with *Dashboard* class that enables an admin to confirm as many reports as possible. The admin does exist even without the submission of any crime report. *SubmitReport* class inherits the attributes of *Dashboard* class, enabling it to upload crime reports alongside users' metadata. The relationship between *Dashboard* class and *User* class shows that a dashboard cannot exist without a user and a user can have either 0 or more dashboards.

b) UML Sequence Diagram: The UML sequence diagram shows the interaction between the objects that make up a software system in time sequence (Al-Fedaghi, 2021). The sequence of messages exchanged between objects needed to carry out a function is also captured in a sequence diagram. Figure 5 shows the UML sequence diagram used in this study with the accompanying objects.

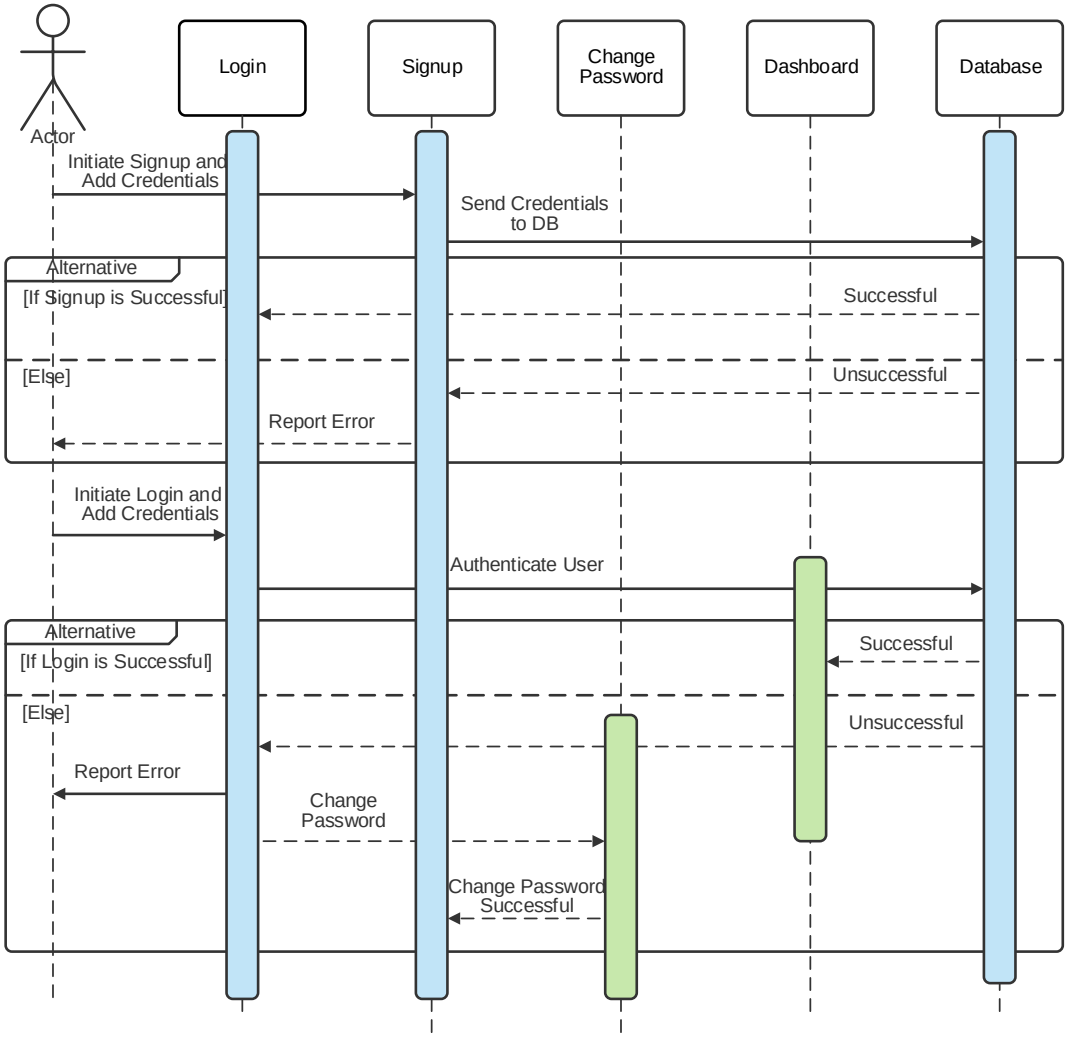


Figure 5: The Mobile App's UML Sequence Diagram

Initially, the user/Actor could go through the *Walkthrough* screen and navigates to the *Login* screen. Alternatively, the user could navigate to the *Signup* screen and initiate registration as a new user. During the process of signup or login, credentials are sent to the *Cloud Database.* The Cloud Database returns a "Successful" or "Unsuccessful" message based on the correctness of the credentials sent. If the process of login is successful, the user is navigated to the *Dashboard* screen, otherwise an error report is provided to the user. The same responses also applicable to the *Change Password* screen.

c) UML Use Case Diagram: The UML use case diagram of the mobile app shown in Figure 6 was used to graphically represent the possible interaction of a potential user (eyewitness) with the mobile app (Acharya *et al.*, 2014).

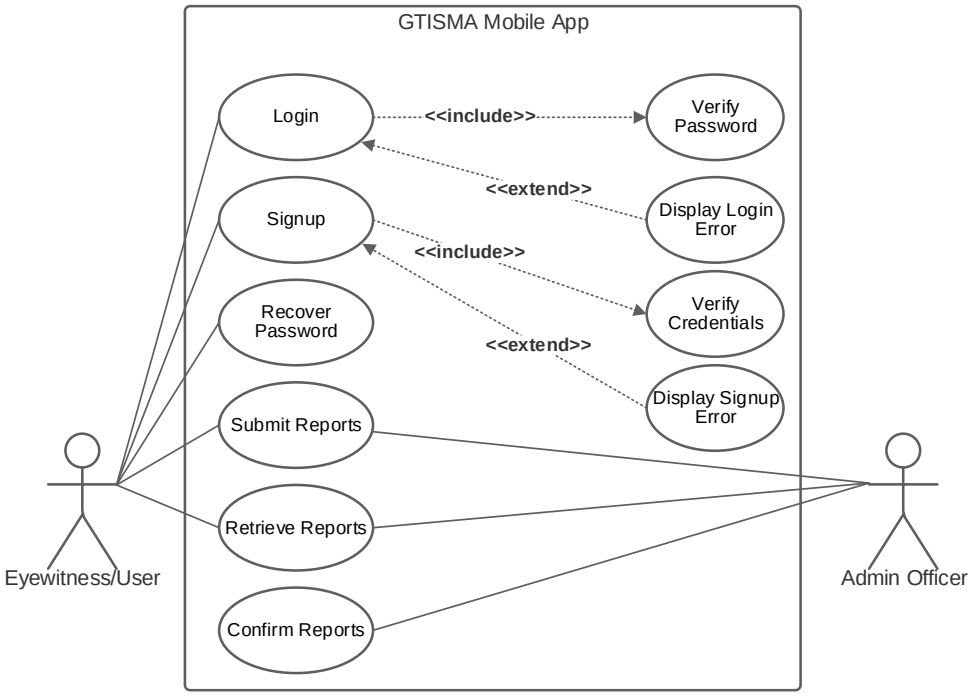


Figure 6: The Mobile App's UML Use Case Diagram

The UML Use case diagram includes functional requirements such as *Login*, *Signup*, and *Submit Reports.* When a user attempts to login, a password verification process is initiated. If the process is unsuccessful, then an error message is displayed. The same process is applicable to the Signup process. Submitted crime reports can be confirmed only by the Admin.

Mobile Application System Implementation

The mobile application's main architecture is based on IBM's architecture. The architecture consists of the presentation tier, application tier and data-tier (Figure 7). The respective tiers are discussed in subsequent subsections.

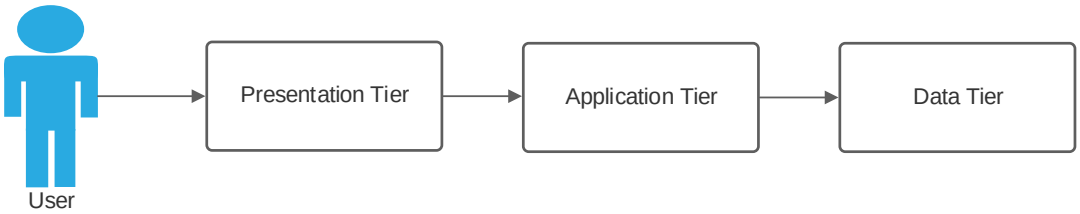


Figure 7: Three-tier Architecture for Enterprise Application [Adopted from IBM Cloud Education (2020)]

Presentation Tier

The presentation tier is the user interface (UI) and communication layer of the software, where the potential user interacts with the app's graphical elements, such as buttons, labels and fields, which determines the look and feel of the mobile app. In addition, information is either retrieved from the user or displayed to the user in this tier of the enterprise architecture layer. In this work, Google's Flutter cross-platform mobile application development SDK, which was installed in Android Studio integrated development environment (IDE), was used to design the app's GUI elements, using Google's Dart programming language. Android Studio includes features such as debugging, multi-configuration simulation capabilities, APK

Analyzer, version control, code auto-completion and intelligent debugging. In order to improve the experience of potential users, elements were either sequentially animated or animated in parallel using the Flutter's *Animation Controller* class.

Application Tier

The application tier is the brain of the mobile app because it is where the business logic of the app is implemented. Custom classes, packages and functionalities are implemented in the application tier. In this study, the BLOC (Business Logic Object Component) design was used, to separate the presentation layer from the business logic. This allows for smooth running of the action, allowing for scalability and maintainability.

Data Tier

Most of the data and information used within the app, such as users' report metadata, comprising of data such as initials, *firstName*, *lastName*, e.t.c., were fetched from a cloud database via an application interface (API). These APIs were specific to the major classes as shown in the UML class diagram. For example, the *signup* API was used to implement registration, while the *login* API was used to implement user login. Hence, the data tier enables the mobile app to communicate with an external database that is hosted on a server on the internet.

System Testing

The performance of the developed mobile application system was evaluated using alpha and beta testing to ensure that the developed system meets its specific functional requirements.

Alpha Testing

Alpha testing was conducted at every stage throughout the mobile app development cycle. This was done to ensure that every module that was added to the mobile app system at each stage behaves as expected with minimal need for fine-tuning. This testing included both functional and non-functional testing to verify the performance, usability and reliability of the mobile app when it finally gets to an end user.

Beta Testing

Beta testing was done after acquiring the minimum viable product (MVP) of the developed mobile app system. This test was conducted by potential real users to rate the performance of the mobile app based on certain criteria, including clarity, usability, attractiveness, and responsiveness. A total of 10 neutral respondents were invited to rate the app based on these criteria. Each index was rated on a scale of 1 to 10, where '1' connotes a poorly-performing index and '10' connotes an excellently-performing index.

Results and Discussion

User Interface

Walkthrough Page

When a new user launches the mobile app, he is first introduced to the walkthrough screen as shown in Figure 8. The walkthrough screen provides the user with an overview of what the function of the app and what value the app should provide to the user. In order to improve user experience, users could choose to interact with the app by selecting a preferred language, which include English, Yoruba, Igbo and Hausa. The remainder of the walkthrough contains specific information about the app.

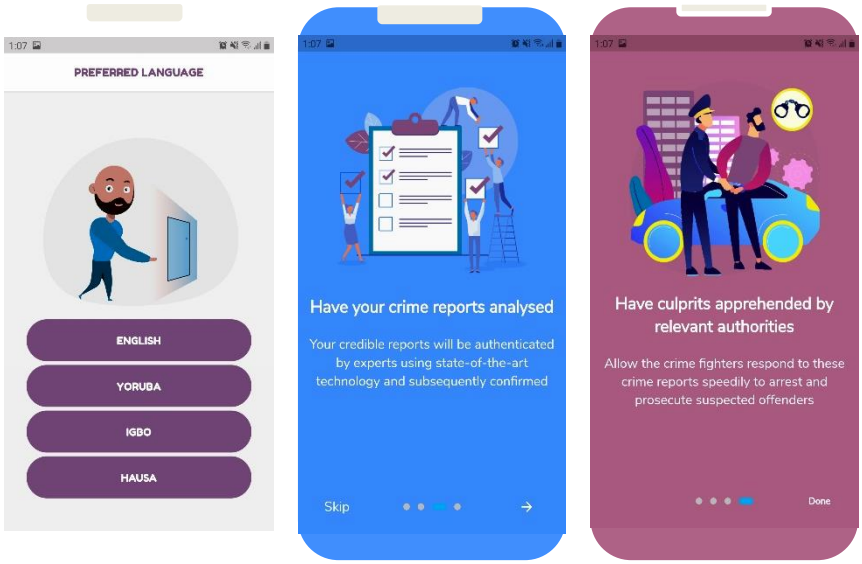


Figure 8: Walkthrough Page of the Mobile Application

Accreditation Pages

The accreditation pages consist of the *Login, Register* and *Reset Password* Pages (Figure 9). After the user has gone past the *Walkthrough* pages, he is navigated to the *Login* page. An already-registered user would login by providing email and password credentials and clicking on the submit button. However, a new user who has not created an account on the platform would click on the "signup" button to commence registration. Clicking the "signup" button navigates the user to the *Register* page, where the user enters basic information such as phone number, password, gender and email address and initiates the registration process by clicking on the continue button. A user who has forgotten his password credential can reset password by clicking on the Forgot password button located on the Login page, which gets him navigated to the *Reset password* page.

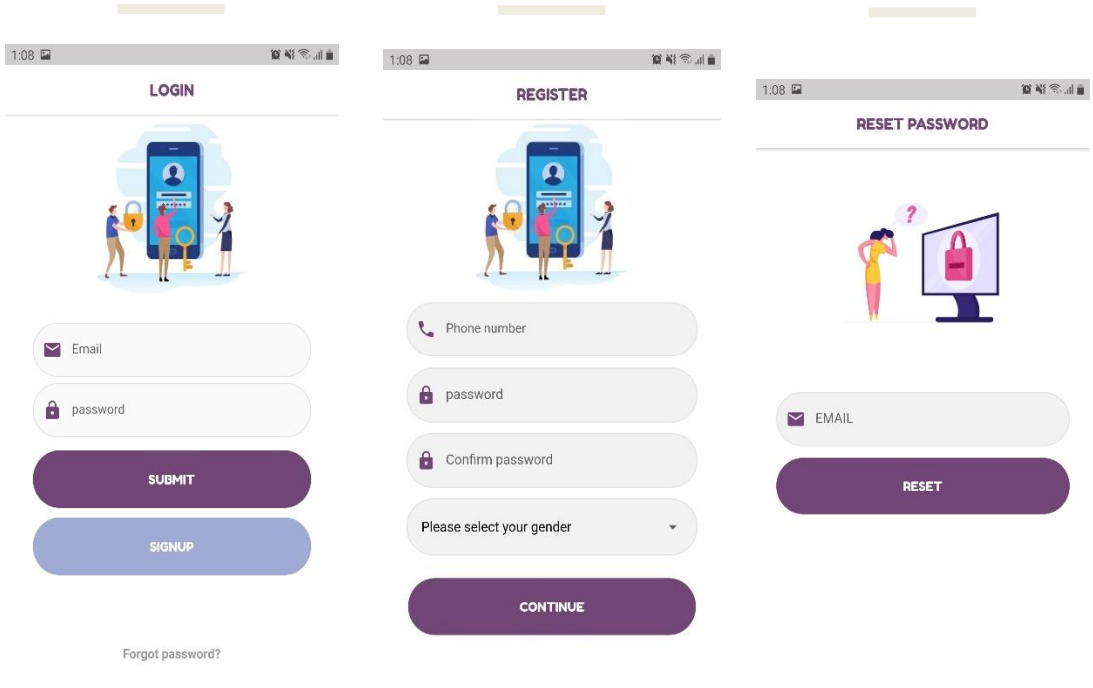
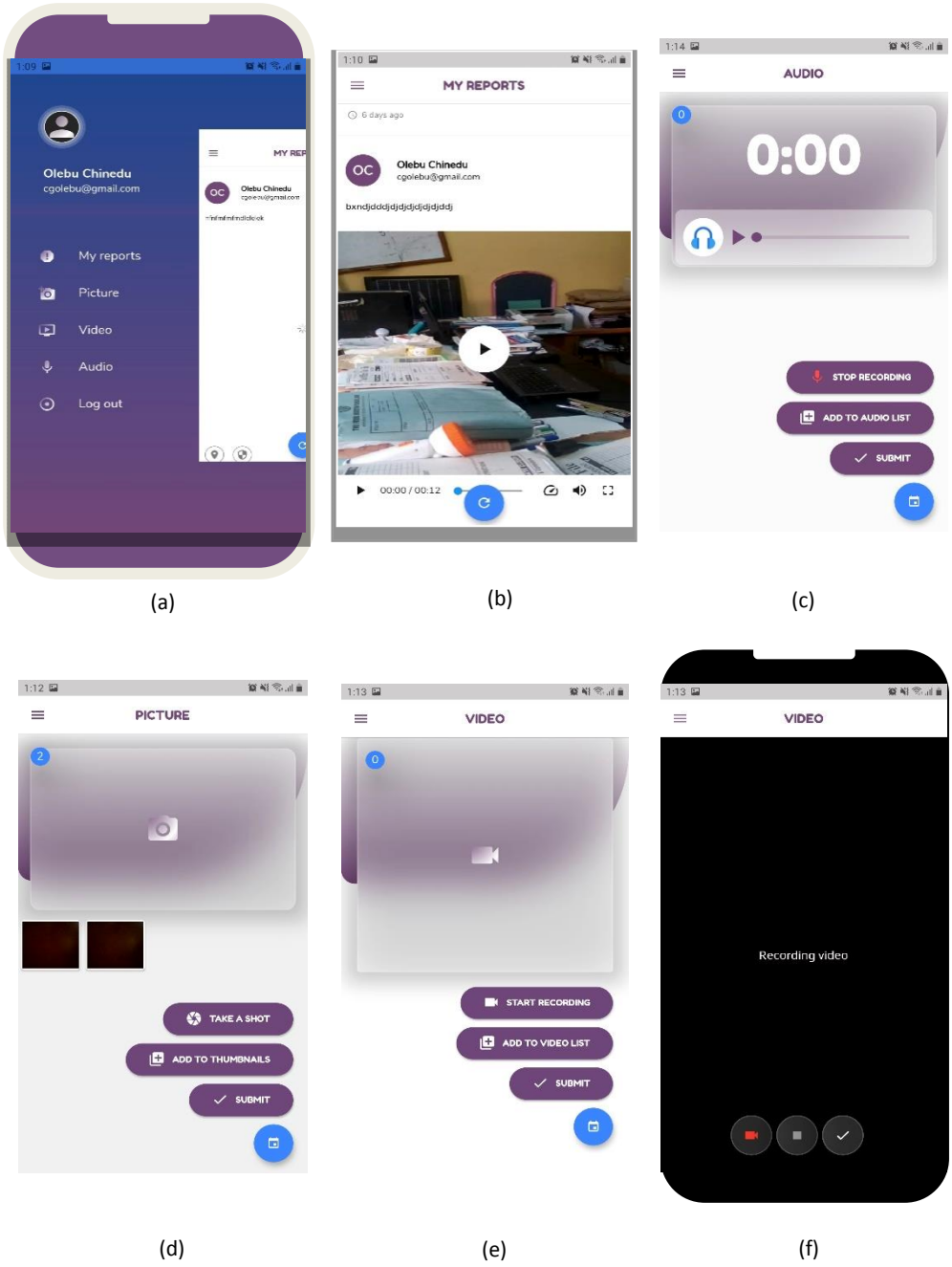


Figure 9: Accreditation Pages

User Dashboard

A user who has successfully logged in to the mobile app would have instant access to his personalized dashboard as shown in Figure 10. There is a navigation pane on the left-hand side of the dashboard, which have a list of action that can be taken, namely *My Reports*, *Picture*, *Video*, *Audio*, and *Log out* [Figure 10(a)]. The *My Reports* reveals a screen that presents a list of all crimes cases reported by a potential user. The reported crime could be in video, audio, pictures, or textual format. Video and audio reports can be reviewed easily using the playback feature that has been integrated with the list of reports [Figures 10(b-f)]. The status of each reported cases can be seen on the right bottom corner of each report card. Users can capture an ongoing crime screen by using the *Picture* option on the navigation pane.

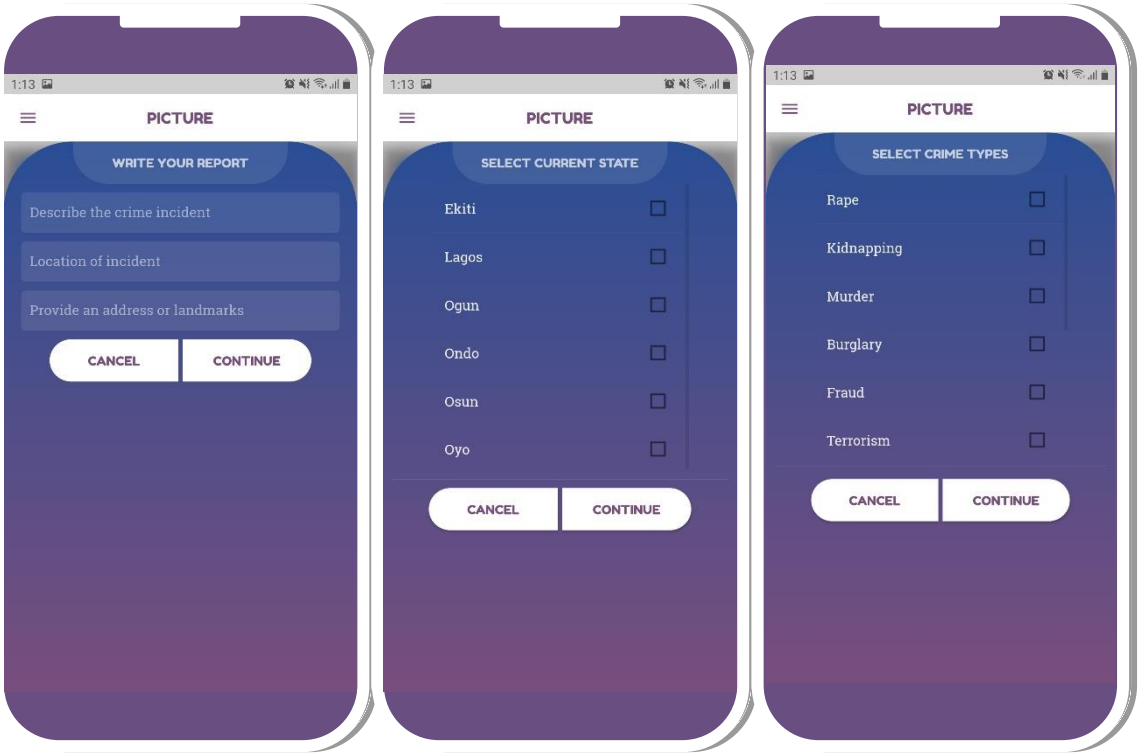


(a) (b) (c)

(d) (e) (f)

Figure 10: User Dashboard (a) List of action screen, (b) My Reports screen, (c) Audio reporting screen, (d) Picture screen, (e) Video reporting screen, and (f) Video recording screen

The Picture option reveals another screen where photos of crime screens can be captured and curated for submission. Similarly, the *Video* option reveals a screen for recording video feed from crime scenes. The audio button also reveals a screen for recording voice conversations in a screen. The submit button shown by clicking the floating action button reveals a modal view where users provide information such as the description of the crime incident, location of the crime incidents and possible landmarks that could help investigators locate the crime scene [Figure 11(a)]. The continue button reveals a page where users select the state from which the crime is being reported [Figure 11(b)] and finally, the user selects the type of crime being reported [Figure 11(c)].



(a) (b) (c)

Figure 11: Report Submission Process for Picture option (a) Report writing screen, (b) Current State selection screen, (c) Crime Type selection screen

Performance Evaluation

The evaluation results of the beta testing were obtained and presented as shown in Table 1.

Table 1: The Developed Mobile Application Evaluation Rating

User Index	User Interface	Functionality	Clarity	Maintainability
1	9	9	8	8
2	10	9	10	9
3	8	8	8	9
4	10	10	10	9
5	10	8	9	8
6	10	9	8	8
7	9	10	10	9
8	8	9	9	9
9	10	10	8	8
10	10	9	9	9
Average Rating	9.4	9.1	8.9	9.4
Percentage Rating	94%	91%	89%	94%

From Table 1, the percentage performance ratings obtained organically for the *User Interface*, *Functionality*, *Clarity* and *Maintainability* are 94%, 91%, 89% and 94%, respectively. This shows that the developed mobile application performs satisfactorily and effectively serves its purpose.

Conclusion

We have developed a software system for real-time crime reporting and management for southwestern Nigeria which we named GTISMA. The GTISMA provides a seamless platform for reporting, monitoring and approving crime incidents, and is a dual software solution: the user-centered mobile application, and the administrative web application. This paper described the mobile application component of the software solution. The mobile application component facilitates real-time crime reporting from the scene of the incident by an eye witness via a cloud service to the office of the law enforcement agency. The mobile application incorporates technologies such as location tracking, video recording, audio recording, amongst other intriguing features. Tests conducted by ten real users (volunteers) based on certain criteria of clarity, usability, attractiveness and maintainability showed that the developed mobile application performed satisfactorily and can effectively serve its purpose. The mobile application has been published on Google Play Store, and is installable on both Android smart phone and IOS devices.

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